Salt vs. Sugar: A Microscopic to Macroscopic Match-Up

Unit	Utah SEEd Standard / NGSS Performance Expectation	Estimated Lesson Time:
CHEM 2.2 **Structure and Properties**	Plan and carry out an investigation to compare the properties of substances at the bulk scale and relate them to molecular structures. Emphasize using models to explain or describe the strength of electrical forces between particles. Examples of models could include Lewis dot structures or ball and stick models. Examples of particles could include ions, atoms, molecules, or networked materials (such as graphite). Examples of properties could include melting point and boiling point, vapor pressure, solubility, or surface tension. (PS1.A)	Two 60-minute classes

Lesson Overview

Learning Objective

Students will plan and carry out an investigation that compares bulk-scale properties (for example: melting point, solubility, or conductivity) of substances, use measurements to infer the types of particles present, and use models such as a PHET simulation to explain how differences in the strength of electrical forces between particles produce the observed properties.

Anchor Phenomenon

Students will see a teacher demonstration of salt vs. sugar as it is crushed between a folded cardstock and discuss what observations they can make when seeing the results under a microscope. Then, students will experience graphite vs. coal under a conductivity tester, and then discuss the different properties between coal, graphite, and diamonds, as they are all made of carbon. Students can then start to think about the following question:
Why is graphite used in pencils, coal used for fuel, while diamond is used in cutting tools — even though all are made of carbon?

Driving Question

What is the connection between the observable (macroscopic) properties of substances and its molecular structure?
Why is graphite used in pencils, coal used for fuel, while diamond is used in cutting tools — even though all are made of just carbon?

Lesson Level Performance Expectations

Plan and carry out an investigation to compare the **properties of substances** at the **bulk scale** and relate them to **molecular structures**. Emphasize using **models** to explain or describe the strength of **electrical forces** between particles.

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Lesson Snapshot

Lesson Summary:

	Estimated Time	Section Overview	How are students answering the driving question or meeting the learning objectives? (Highlight SEPs, DCIs, and CCCs)
Experience the Phenomenon	10 –15 min	Students examine and compare the macroscopic properties of carbon-based substances and two crystalline solids, salt and sugar. Observing conductivity prompts students to hypothesize about microscopic bonding.	The stage is set for students to **investigate** and how observable **macroscopic** results connect to unobservable atomic arrangements.
Investigate the Phenomenon	40-50 min	In this investigative phase, students work collaboratively to design and execute tests comparing **sugar and salt.** Teams formulate a plan, identify variables, and collect data from their chosen experiments. Finally, they analyze their results to infer the **microscopic structure** and bonding differences between the two substances, ranking the usefulness of each test in revealing these underlying concepts.	Using their **investigations** results students can make observations about **structure** they cannot see like charged atomic particles with conductivity tests. The macroscale observations help students understand the molecular electrical forces.
Model the Phenomenon	40 min	Students transition from macroscopic observation to **molecular modeling** after receiving instruction on **ionic and covalent bonding**. They choose an experimental result (e.g., conductivity) to create and then revise a **structural model** for salt or sugar, using labels and arrows to explicitly connect the strength of **electrical forces** (bonds/intermolecular forces) to the substance's bulk property. The section concludes by referencing students back to the carbon phenomenon.	Students make **molecular scaled models** of one of their investigations. They use both symbols and images to convey how the molecular atoms behave in regard to the property chosen, which all touch on electrical forces, bonds, or intermolecular forces.

Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts
NGSS Appendix E The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes.	NGSS Appendix F **Planning and Carrying Out Investigations:** Students must collaboratively **design and execute investigations** that provide quantitative data to test and refine models, ensuring variables are	NGSS Appendix G **Scale, Proportion, and Quantity** alongside **Structure and Function** to explain matter. This requires students to **compare and contrast macroscopic properties** (the bulk scale) with the **arrangements of atoms and bonds** (the

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Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart.	controlled and the precision/limitations of the data collected are properly considered. **Developing and Using Models:** Students are expected to **synthesize, develop, or revise complex models** (physical, mathematical, or computational) based on evidence to **illustrate and predict** the relationships and mechanistic accounts between components within a system. Both practices require students to **evaluate the merits and limitations** of their models or investigation designs against empirical evidence and scientific principles to build and justify their scientific explanations or engineering solutions.	molecular scale), recognizing that the specific **atomic structure determines the material's function.** Students must use models and scale factors to understand that **observable changes are direct consequences** of changes in particle arrangements, thus establishing a powerful link where **the arrangement of components at one scale dictates the specific functions and properties** observed at the larger, bulk scale.
Related knowledge and skills from prior grades		
Disciplinary Core Idea: PS1.A Structure of matter (includes PS1.C Nuclear processes) [NGSS Appendix E]() The fact that matter is composed of **atoms** and **molecules** can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter. Matter exists as particles that are too small to see, and so matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials. Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	Science and Engineering Practices [NGSS Appendix F]() Planning and Carrying Out Investigations • Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or solutions. • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. • Evaluate the accuracy of various methods for collecting data.	Crosscutting Concept: Structure and function [NGSS Appendix G]() Structure and function In grades 6-8, students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function. They design structures to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. Scale, Proportion and Quantity In grades 6-8, students observe time, space, and energy phenomena at various scales using models to study systems that are too large or too small. They understand phenomena observed at one scale may not be observable at another scale, and the function of natural and designed systems may change with scale. They use proportional relationships (e.g., speed as the ratio of distance traveled to time taken) to gather information about the magnitude of properties and processes. They represent scientific

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	• Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. ▯ Collect data about the performance of a proposed object, tool, process or system under a range of conditions. Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Evaluate limitations of a model for a proposed object or tool. • Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms. • Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	relationships through the use of algebraic expressions and equations.

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Materials

Link to all materials on the 3DRST website (3drst.byu.edu): https://3drst.byu.edu/chem-2-2-saltsugar
Link to all materials on Canvas Commons: https://tinyurl.com/3DRSTchemistry

Student Materials	Teacher Materials	Lab Materials/Other Resources
- Salt vs. Sugar Student Worksheet - Salt vs. Sugar Student Worksheet (SPED version) - Macro Micro Explanation Modeling and Explanation - Lab Procedure Handout - Molecular Structure & Bulk Properties Formative Assessment - Extension Activity: Salt vs. Sugar Post Lab	- Sugar v Salt Teacher Slides - Teacher set-up instructions for each test - Procedures for each test - Helpful teacher notes for each test - Molecular Structure Investigation: Expected Results and Reasoning - Video: Paper conductivity Link to Simulation: https://phet.colorado.edu/en/simulations/sugar-and-salt-solutions	**Available Supplies for Students** - Sugar / Salt – 2g Limit - Well plate - Water (Tap and Distilled) - Dark Colored Cardstock - Mineral Oil - Droppers - Conductivity Tester - Hot Plate / Candle - Foil Squares - Beakers - Thermometer - Toothpicks - Spoons or Scoopulas - Magnifying Glass - Mortar and Pestle - Saturated solutions **Other Supplies** - Microscope - Ethanol - Hammer - Graphite - Coal - Diamond (picture)

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Lesson Preparation

Material Preparation:
Before the lab begins, ensure all materials are organized and prepared at each station. Each group should have small, labeled containers of sugar and salt (no more than 10 grams each), along with beakers for mixing and testing. Prepare both tap water and distilled water in clearly labeled bottles, and include small amounts of mineral oil for comparison. Set out well plates lined with foil squares for heating tests using either a hot plate or a candle, following proper safety procedures. Provide droppers, spoons or scoopulas, toothpicks, and a mortar and pestle for crushing and mixing samples. Have conductivity testers, thermometers, and magnifying glasses or microscopes available to observe physical and microscopic properties. Use dark-colored cardstock as a background to help students see crystal shapes more clearly. Lastly, pre-mix saturated solutions of sugar and salt for students to examine during the experiment.

Required Previous Knowledge:
Before starting this lab, students should understand that all matter consists of atoms, which combine to form molecules and compounds. They should be familiar with the basic layout of the periodic table and the general properties of different element groups, such as metals and nonmetals. Students should also be able to describe and recognize examples of physical and chemical properties. Although they may not yet understand the difference between ionic and covalent bonds, this lab will serve as an introduction or reinforcement to those bonding concepts as they explore the distinct structures and behaviors of salt and sugar.

Supports students will need/adaptations:
The lesson materials include a scaffolded version of the lab with guided steps for various investigation ideas. This adaptation is designed for struggling students or to save time. There is also a version that asks students to develop their own procedures to investigate the molecular properties of salt and sugar.

Vocabulary Definitions:
These vocabulary words are central to understanding how the microscopic structures and bonding types of salt and sugar give rise to their distinct physical and chemical properties—core ideas in the study of matter and its interactions.

- **Ionic Bond/Compound –** A type of chemical bond formed when electrons are transferred from one atom to another, resulting in positive and negative ions that are held together by strong electrostatic forces. Salt (sodium chloride) is an example of an ionic compound.
- **Covalent Bond/Molecule –** A chemical bond where atoms share electrons to form stable molecules. Sugar (sucrose) is an example of a covalently bonded molecule.
- **Electrostatic Force/Attraction –** The force that holds charged particles together. In ionic compounds, it is the attraction between positively and negatively charged ions.
- **Solute –** The substance that dissolves in a solvent to form a solution. In this lab, sugar or salt acts as the solute when mixed with water.
- **Solvent –** The substance that dissolves another material. Water is the solvent in this investigation.
- **Electronegativity –** A measure of how strongly an atom attracts electrons in a chemical bond. Differences in electronegativity help explain why salt forms ionic bonds and sugar forms covalent bonds.

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- **Solubility –** A measure of the maximum amount of a solute that can dissolve in a specific amount of solvent at a given temperature governed by electrical forces.

EXPERIENCE THE PHENOMENON/PROBLEM (ENGAGE)

What Students Are Doing	Teacher Tips
Students begin by examining slides or samples of carbon allotropes—graphite, diamond, and coal. They hold and observe each substance, recording its physical characteristics, such as color, texture, luster, and streak color. Students then observe a demonstration of conductivity testing with graphite and coal, noting that graphite conducts electricity while coal does not. After learning that they are all allotropes of carbon, students hypothesize and discuss why they behave differently. Next, students make detailed observations of sugar and salt. They should recognize that both appear as white crystalline solids that look very similar to the naked eye. Using magnifying lenses or microscopes, students examine the shape and structure of the crystals and record their observations in their lab notebooks. Afterward, they share their findings and discuss similarities and differences as a class. To conclude, students participate in a guided discussion that addresses the investigation's driving questions. They propose possible experiments or tests that could further reveal the microscopic structure and bonding differences between sugar and salt, connecting their ideas to the observed macroscopic properties.	Provide a streak plate example, or just scratch a piece of paper with a piece of coal and graphite to show the differences. The graphite on paper can also conduct electricity! See video: Paper conductivity. Remind students that conductivity is related to how freely electrons can move within a structure.
What Teachers Are Doing	**Teacher Tips**
Hand out the student worksheet to each student. Project **slides 1-8**. Review the lesson objective, then instruct students to identify the SEP, CCC, and DCI on their worksheets. Have the students observe coal, diamond, and graphite. Demonstrate the conductivity of the substances and ask them why graphite conducts electricity, but coal and diamond don't. You might need to discuss the uses of coal, diamonds, and graphite. Point out that the three substances are all just made of carbon. Students should be thinking about what is different at the microscopic level (bonding) that makes substances have different properties. Students should watch a teacher demonstrate that graphite conducts electricity, but coal does not. Instruct students to write 3 questions and 3 observations about what they observed when they looked at the sugar and salt. Have students share their ideas with the group and/or the class.	If you do not have a conductivity meter, you can create a simple circuit.

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Discuss the driving question with the students. Prompt them to come up with ideas for experiments that they could do to help understand the microscopic or molecular nature of sugar and salt.	

INVESTIGATE THE PHENOMENON (EXPLORE)	
What Students Are Doing	**Teacher Tips**
Students identify hot plate safety questions on the worksheet. Students review the driving questions and available materials. They then decide, with the team member, which tests to conduct from the list (scaffold) or to create their own. They then make a plan or review the steps to complete the test. They will identify the variables and indicate how they will gather data for the experiment. Next, the team will carry out their planned tests, recording their sugar vs. salt results in the indicated sections of their worksheet. After reviewing the results, students ponder whether the test helps them understand the substance at a microscopic level. Students fill out “how does it help you, "see the microscopic” section, and the Helpfulness ranking. Students collaboratively assign the rankings and make inferences about the molecular structure. Students clean up their areas, unplug devices, and return equipment if necessary.	A 2g limit for salt and sugar is plenty if you use well plates. Restaurant salt and sugar packets are perfect for this activity. Walk around to ensure students understand the results. If you need help understanding the results, refer to the “**Molecular Structure Investigation: Expected Results & Reasoning**” handout
What Teachers Are Doing	**Teacher Tips**
Review with the students the criteria and constraints for the investigation (**slides 8-15**). Review the safety slides and address any questions students may have about using the equipment you are providing. Tell the students that they have 30 minutes to plan and carry out their investigations. Set a timer and have the students begin. Rotate around the room, answering questions and ensuring students follow safety procedures. When the time is over, have students clean up and return their supplies.	Consider showing students the results-and-reasoning handout before they begin their modeling portion: “**Molecular Structure Investigation: Expected Results & Reasoning.**”

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MODEL THE PHENOMENON (EXPLAIN)

What Students Are Doing	**Teacher Tips**
Students take notes during the teacher's lecture on modeling and covalent vs. ionic bonds. Students choose one of the tests to create a model. Their initial model should use appropriate representations (e.g., a repeating crystal lattice for salt; discrete molecules for sugar). The model should use arrows, labels, or color-coding to **describe the strength and type of the electrical forces** (ionic bonds, intermolecular forces, solvent-solute interactions) that explain the chosen property. Next, students observe the PhET simulation of salt and sugar in solution and see other examples of modeling, such as melting and conductivity. They then read the handout corresponding to their model. Students use insights gained from the class review, simulation, and handouts to critically revise their initial molecular model. They must ensure the model clearly connects the type of bond/force to the specific bulk property they chose. Groups share their revised models with another group, explaining their chosen property and how their model uses the strength of electrical forces to explain the result. The class revisits the initial phenomenon (e.g., coal, diamond, graphite) and the driving questions. Students apply their new understanding of structure and bonding to explain why materials made of the *same element* (carbon) can have wildly different bulk properties (soft/slippery vs. the hardest substance on Earth).	The handouts from **Macro/Micro Models and Explanation for Students** will help with the sense-making portion. Read over the materials to help students get ideas for improvement.
What Teachers Are Doing	**Teacher Tips**
Review Lewis structures and molecular formulas for sugar and salt. Go through the remaining slides. Pause on **slide 20** so they can try a model on their own. Then complete the remaining slides, providing more information on modeling ideas. Review the Lewis dot structures and molecular formulas for salt (NaCl) and sugar (C12H22O11). Review the foundational differences between **Ionic Bonds** and **Covalent Bonds** as needed, emphasizing that ionic bonds involve charge transfer and strong, long-range attraction, while covalent bonds involve shared electrons and result in neutral molecules. Demonstrate how salt and sugar are typically modeled (e.g., using a **ball-and-stick** model for sugar's molecules vs. a simplified **Lewis dot** or repeating lattice for salt's ionic structure).	You might want to make a class model of the molecular structures for each substance, then compare it with what they find online. Link to Simulation: https://phet.colorado.edu/en/simulations/sugar-and-salt-solutions Other molecular model examples:

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Direct students to their groups. Instruct them to choose **one** test result (e.g., conductivity in water, melting point, or brittleness) to construct their **Initial Model**. Circulate and coach groups to ensure they use arrows and labels to describe the **strength and type of electrical forces** responsible for the property. *The goal is for students to generate a model independently before receiving additional resources.* Wait until students have completed their initial models. As a class, view the **PhET simulation** (or other digital resources/slides) demonstrating the behavior of ionic and covalent substances in solution (dissolving) or when heated (melting). Pause the simulation to highlight the key difference in particle interaction and movement. Next, pass out the information for the model they are working on from the "**Macro/Micro Models and Explanation for Students**" section. Give students time to read it over. *Only use the extra informational slides or resources if all students need help clarifying core concepts.* Instruct students to immediately use the insights gained from the class review and simulation to **critically revise their initial molecular model**. Emphasize the requirement that the model must clearly show the connection between the **type of bond/force** (e.g., strong ionic bond vs. weak intermolecular force) and the specific **bulk property** they chose Have the students share their models with the rest of the class. Instruct them to share their revised model with another group, explaining their chosen property and how their model uses the strength of electrical forces to explain the result. Listen for students using precise vocabulary (**ionic**, **covalent**, **intermolecular forces**) Revisit the initial phenomenon slide featuring **coal, diamond, and graphite**. Challenge students to apply their new understanding of structure and bonding to explain why three substances made of the same element (Carbon) can have radically different bulk properties (e.g., diamond's hardness due to a network covalent structure versus graphite's slipperiness due to weak intermolecular forces between layers).	Hydrocarbons - javalabs Salt - javalabs Simple Chemical Bonding- javalabs

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POSSIBLE EXTENSIONS/ALTERNATIVE ADAPTATIONS

Predictive Sorting Challenge:
Objective: Reinforce the connection between bonding type and properties. **Activity:** Provide students with data for 8 *new* substances that are either ionic or covalent. The data should include melting point, conductivity, and solubility. Students must use their models (ionic vs. covalent) to predict the bonding type for each new unknown based on the macroscopic bulk data. They then categorize each into its microscopic bond type, helping students see that observation can help us identify molecular-scale bonds between atoms.

The Role of Water in Understanding Molecular Forces:
Objective: Explore the "like dissolves like" rule using a full spectrum of solvents. **Activity:** Test the solubility of salt and sugar not just in water and ethanol, but also in a highly nonpolar solvent (e.g., hexane or mineral oil, as you suggested earlier) and a polar but aprotic solvent (if available). Students create a model showing that a nonpolar solvent is incapable of breaking the strong ionic bonds, or even the weaker hydrogen bonds, required for dissolution.

This lesson was created by Jamie Carling, Anna Lewin, Rachel Trujillo, and Mike Sanderson

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